SYNOPSIS OF AMERICAN CARBONIC CALYPTRÆIDÆ.

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There has always been a considerable diversity of opinion as to what term should really be applied to that paleozoic group of gasteropodous shells commonly referred, by most American writers, to *Platyceras* of Conrad. . The described species of this group have been variously and indifferently assigned to *Capulus* Montfort,[1] *Pileopsis* Lamarck,[2] *Actita* Fisher von Waldheim,[3] *Platyceras* Conrad,[4] *Acroculia* Phillips,[5] *Orthonychia* Hall[6] and some other genera. Of these *Capulus* and *Platyceras* have become at last generally adopted; the former having preference with most European, and the latter with the majority of American authors.

Generic Considerations. It may be premised here that the two genera just mentioned are practically coextensive; and since the first has precedence—of more than thirty years—it should be used instead of the second. Even if the group to which Conrad gave the name *Platyceras* is a valid one it is very questionable whether the term could stand, inasmuch as it has been preoccupied for three-quarters of a century. It has long been known that Geoffrey in 1764 proposed for a genus of coleoptera the name *Platyceras*,[7] a term which was later employed by Latreille [8] and which continues to the present day in good usage as originally proposed. Taking advantage of this fact Œhlert [9] has recently revived Phillips' name *Acroculia* for the *Platyceras* group of shells; but this of course cannot be adopted.

As regards the actual generic characters of the various species, their specific limitations, range of variation and the distribution in time and space of the different varieties, greater confusion has,

[1] Conch. System., vol. II, p. 54. (1810.)
[2] Anim. sans Vertebr., t. VI, (2), p. 16. (1822.)
[3] Mem. de la Soc. imp. d. Naturalistes de Moscau, t. VI, p. 234. (1823.)
[4] Ann. Rep. N. Y. Geol. Sur., p. 205. (1840.)
[5] Palæ. Foss. Cornwall, p. 93. (1841.)
[6] Rept. 4th Dist. N. Y., p. 172. (1843.)
[7] Hist. abrégée des Insectes, 1764.
[8] Précis des caractères des Insectes, 1796.
[9] Bul. de la Soc. Géol. de France, (3), t. XI, p. 602.

perhaps, nowhere existed among fossil mollusks than in the group under consideration. This utter lack of agreement among writers is directly traceable to a number of causes: the majority of the species have been described from very few or single specimens, with little regard to the forms already known; no attention whatever was paid to variability and indeed the range of the latter has only very lately been made out with any degree of certainty; comparisons with individuals from localities more or less widely distant have been made only in exceptional cases.

General Features. The leading characters of generic value in modern Capulus, as shown by the more typical shells, as *C. hungaricus* Linnè, are the obliquely conical shape, the small, often closely incurved or coiled spire, the broad campanulate apertural portions and the peculiar horse-shoe-shaped muscular impressions. In the paleozoic forms heretofore referred to *Platyceras* these features have been made out most clearly in *C. paralius* (W. & W.) and *C. equilateralis* (Hall); though the affinities are not less striking in many other species.

In a group of more than three hundred described paleozoic species having so few salient characters for classification and such a great range of variation as the forms assigned to *Platyceras* it is hard to foresee the difficulties in attempting to arrange satisfactorily the many different forms. The genus may ultimately admit of a suitable separation into several more or less well marked subdivisions; and the many forms make such an arrangement very desirable. It can, however, only be accomplished after a careful and critical revision of the entire group. The placing of *Platyceras*, *Orthonychia*, etc., as subgenera under *Capulus*, as has been done by Zittel[1] and others, manifestly does not meet the requirements, at least in so far as the American species are concerned. It is probable that all of the described Platycerata cannot be included under *Capulus*. Just which ones, remains for future comparisons to decide. There seems to be good ground for believing that further study will show that a number of the paleozoic forms in question belong more properly to genera closely allied to *Capulus* rather than to *Capulus* itself. This would carry back the antiquity of certain modern genera farther than has hitherto been considered possible. A recent critical examination of certain described Platycerata also discloses that they belong to families entirely different from those supposed.

[1] Handbuch der Palæontologie, II Band, p. 216.

General Relations. There is often considerable embarrassment in attempting to separate certain paleozoic Capuli, on the one hand from some forms of *Platystoma*, especially from those species in which there is a greater or less tendency for the shells to uncoil; and on the other hand from various genera of Patelloid shells. As might be expected in a group of gasteropods presenting so few constant characters, which can be satisfactorily relied upon as classificatory criteria, it is often impossible to clearly distinguish between certain of these species. Many structural features long regarded as of much importance in identification have recently [1] been shown to possess very little, if any, specific value, owing to their great variability. It has therefore become necessary to consider as of the utmost significance, the basing of species upon general resemblances rather than upon unimportant varient characters arising from the diverse conditions of environment imposed by a more or less extensive geographic and geologic distribution. Therefore in choosing for classificatory purposes the characters of any group it is evident that only those features exhibiting the least tendency to modification are available. Even the most constant structures appear to lose much of their stability at some period during the existence of the group—whether specific, generic or family; while other characters more or less variant in the earlier stages of development, later become less liable to change. At some time these features blend and thus appear the transitional forms. It may be assumed, then, that in many groups of the same genetic origin some varieties will present features that have remained for a long time practically unmodified; while others exhibit the same characters in a highly specialized, but ever changing condition. And it is of great interest to note that the latter—those having greatly exaggerated features—are the forms whose existence is of comparatively short duration; and that with these intensified structures the development is rather rapid, while their culmination results in a great diminution of the group's vitality, or more commonly its extinction.

Number of Species. Among the first to notice the existence of Carbonic Capuli in the continental interior were Yandell and Shumard, who called attention to the association of a species with an *Acrocrinus* (afterwards described by the former author as *A. shumardi*). These writers attempted to prove that the crinoids were carnivorous in their habits, and that they subsisted on mollusks.

[1] Keyes: Proc. Am. Philosophical Soc., vol. XXV, p. 231.

Capulus acutirostris, however, was the first species of this group of gasteropods described from the Carbonic rocks of the Mississippi basin; and was so denominated by Hall in 1856. The publication of this diagnosis was followed in quick succession by definitions of other forms by Stevens, Hall, Swallow, McChesney, Winchell, White and Whitfield, and Meek and Worthen; so that the total number of species that have been brought to notice from the carbonic rocks of North America is more than two score. A part of this number are, however, to be regarded as synonyms, reducing the actual number of species as now recognized nearly one-half.

I. Habits of the Carbonic Calyptræans.

Variation in Form. It has been noted frequently in the descriptions of various paleozoic species of *Capulus* that the shells often present a more or less well-defined quinquelobate appearance and that the apertural margins are for the most part sinuous or crenate. In the absence of salient classificatory characters these features were regarded usually of much importance for specific distinction. It was not until a comparatively recent date that their true significance was indicated. The fact here referred to is the attachment of fossil Capuli to foreign bodies and particularly to the calyces of crinoids. The observations on this habit of the ancient Capuli has been fully considered elsewhere but may be here briefly summarized by stating that, in all the examples examined—upwards of several hundreds—(1) the gasteropod shell invariably lies over the anal opening of the crinoid; (2) the mollusk remained in this position for a considerable period, probably for the greater part of life, as is shown by the shells on highly ornamented calyces and by the removal of them from their places of attachment and tracing the growth of the shell by the concentric grooves made on the ventral plates; (3) the growing shell followed closely the inequalities of the surface upon which it rested—depressions giving rise to furrows and protuberances to folds or nodes; and (4) shells simply lying on flat surfaces are much more depressed and proportionally broader than those clinging to the vertical or inclined portions of calyces in which the anal opening is situated laterally. The third of these statements is perhaps best illustrated by crinoids having low interradial areas and elevated radial regions and is the probable explanation of the frequent occurrence of the more or less distinctly five-lobed calyptræan

[1] Proc. Am. Philosophical Soc., vol. xxv, 1888.

shells. Heretofore this phenomenon has admitted of no direct causal interpretation.

Attachment to Crinoids. The adherence of gasteropods of the genus under consideration to fossil crinoids was at first thought to furnish conclusive evidence of the carnivorous habits of the Crinoidea; and inasmuch as it was at that time considered that the aperture in the vault was the mouth, this explanation seemed very plausible. Consequently the conclusion was very naturally reached that the crinoid, when it perished, was in the act of devouring the mollusk. Meek and Worthen[1] appear to be the first to question the prevalent opinions regarding the intimate association of crinoid and gasteropod; and to suggest that the mollusk was, in all probability, stationed on the echinoderm for a protracted period, perhaps even for the greater portion of its life. But notwithstanding the fact that the univalve was almost invariably situated over the ventral aperture, and that this opening was recognized as the anus, these writers do not seem to entertain for a moment the idea that the gasteropod may have been nourished upon the refuse matter from the crinoid. The latter view more recently has been preferred by Wachsmuth and is now favorably received by other paleontologists. In every instance of the several hundred specimens lately examined the calyptræan covers the anal opening of the crinoid; and, so far as observable, it is always the anterior portion of the molluscan shell that is directed toward the vault aperture. In those examples where the shell has been removed its impression made on the ventral surface shows that the anterior margin of the peristome was at the edge of the opening in the dome—a position that would have brought the mouth of the mollusk directly over the anus of the crinoid. From an examination of the concentric markings made by the molluscan shell on the vaults of *Strotocrinus* (Plate II, fig. 7) and some other genera, it appears that the forward end of the Capulus was always stationary at the margin of the dome opening; and that, as the growth of the shell continued the posterior portion was removed farther and farther from the ventral aperture of the crinoid.

The food of recent crinoids consists chiefly of animalcules and microscopic plants and the living Calyptræidæ subsist on food of a similar nature. From analogy it might be inferred that the food of fossil crinoids and mollusks must have been like their modern representatives. So far as the echinoderms are concerned there seems

[1] Proc. Acad. Nat. Sci., Phila., 1868, p. 340, *et seq.*

to be no serious objections to this inference. But with the univalves their position through life indicates that their sustenance was, in great part at least, of a somewhat different character.

The anatomy of the crinoid and the position of the molluscan shell are not in accord with the supposition that the calyptræan may in any way have been nourished on the food of the crinoid. This would imply that the gasteropod was parasitic in its habits, a view which, though held by most writers, does not appear to be structurally substantiated. While no doubt the Capulus derived the greater part of its food from excrementitious matter, nourishment from other sources may also have been obtained and in all probability it was very similar to that of the crinoids and the living Calyptræidæ. Furthermore there does not seem to be the slightest indication that the crinoid was in any manner inconvenienced by the attachment of the gasteropod, except, perhaps, in a few cases where the molluscan shell had encircled the posterio–lateral arms, which were in consequence slightly pressed outward. The only really noticeable effect of the presence of *Capulus* on the crinoid is a comparatively shallow depression or groove on some of the vault plates—marking the position of the shell lip; though in the majority of specimens even this feature is not well pronounced (Plate II, figs. 6 and 7). There are no grounds for the view advanced by Trautschold[1] in regard to *Cromyocrinus simplex* Trauts. and its adhering *Capulus parasiticus* Trauts. from the lower Carbonic of Russia. He says: "Es ist nicht unmöglich, dass der oben beschriebene cylindrische Processus der Analplatten zum Schutz gegen diese Verfolger des *Cr. simplex* aufgebaut ist." The "cylindrical process" here referred to is manifestly a ventral sac and therefore was not caused by the presence of the gasteropod.

Illustrative Examples. In some crinoids, as *Gilbertsocrinus*, the plates of the vault are more or less convex or nodose. This nodosity of the ventral plates reaches a high development in such forms as *G. tuberosus* Lyon and Casseday, from Crawfordsville, Indiana. Nearly one-half of the known individuals of this species have a gasteropod adhering. The specimens illustrate well the adaptation of the apertural margin of the shell to the irregularities of the crinoidal surface, for it is clearly observable, as first pointed out by Meek and Worthen, that the contact of the gasteropod shell and crinoid is not the result of accidental pressure, but that the mollusk

[1] Die Kalkbrüche von Mjatschkowa, p. 118.

adhered to the surface of the crinoid for a considerable period, as is shown by the sinuosities of the peristome corresponding exactly to the inequalities of the surface beneath. In young shells the sinuosities of the apertural margin are comparatively much more pronounced than in older individuals. Many of the latter exhibit much irregularity in the lines of growth, which might at first appear to be due to a change of station, but closer inspection shows that this is not the case. When the plates of the crinoidal vault are nodose, as in *Gilbertsocrinus tuberosus*, the lines of growth in adult shells, contrary to the more usual manner among gasteropods generally, are far from being even approximately parallel to one another; and in the lip of the shell a sinus caused by a nodose plate at one period of growth may be represented in the next by a projecting lobe which extended into a deep depression between the nodes of two contiguous plates.

In considering the structural peculiarities of the calyptræan shell three features—the general form, the configuration of the aperture, and the surface markings—appear to have been susceptible of considerable modification as the result of the sedentary habits of the mollusk. An examination of a large series of certain species of *Capulus* reveals the fact that the variant tendency in all three of these particulars is much greater than might be supposed; and when the attachment of these gasteropods to foreign bodies is taken into consideration the causes for such varietal development become manifest. It has been shown that the mollusk doubtless remained fixed throughout a greater portion of life, and that the surface upon which it first settled determined in great part both the form of the shell and the shape of its aperture. When the surface of attachment was flat, as in the vaults of *Gilbertsocrinus* and *Strotocrinus*, the molluscan shell was greatly depressed and the peristome ample; but when the foreign body was strongly convex the shell was more conical, with a comparatively much smaller aperture. It has been stated elsewhere that, in regard to the second of the three variant features observable in the calyptræan shell, the margin of the peristome partakes of all the inequalities of the surface to which the gasteropod adheres. Few of the species attached to crinoids may be said to have true surface ornamentation, for the longitudinal folds or plications in the shell are in many cases due chiefly to the character of the surface of attachment. In some specimens of *Capulus infundibulum* (M. & W.) there have been noticed, in addition to the

undefined longitudinal folds, several series of small conspicuous nodes; but these in all examples seem to result from the peculiar nodose ornamentation of *Platycrinus hemisphericus* with which the univalves are associated.

It appears, then: (1) that some, if not the majority, of the ancient Capuli were stationary during life; (2) that the nourishment of many of these sedentary gasteropods was derived, in great part at least, from the excrementitious matter from crinoids; and (3) that the form of the peristome and its marginal configuration, being dependent upon the surface of attachment, have small value as characters for specific distinction.

The Carbonic species of *Capulus* in which sedentary habits are positively known from the attachment of the gasteropods to echinoderms, together with the various species of crinoids intimately associated, are given in the accompanying synoptical table, page 158.

Range of Variability. Among modern gasteropods attention of late has been called frequently to the variation in the form of the shell as the result of differences in the local conditions of station. In the extension of this inquiry to fossil groups many difficulties are met with, among which the most formidable, perhaps, is the inability to obtain enough material for an adequate consideration of the subject. Usually the shells of any one species are not abundant locally, nor is the representation from localities, more or less widely separated geographically, sufficient to permit of satisfactory comparisons. Lately *Capulus* has unexpectedly furnished a very interesting series illustrating the range of variation in several species. The comparison is perhaps most striking in the projection of ten specimens of *Capulus equilateralis* as recently [1] graphically represented. The case referred to is only a single one of many to be found among the mollusca. It is very significant in its bearing upon the true basis of species; and indicates plainly that, in attempting to separate specimens specifically, too much stress should not be placed upon individual characters.

Other Causes of Variation. In connection with variation of species it is of great interest to note the apparent effect of gravitation in altering the form of some gasteropod shells. This phase can be more satisfactorily considered in *Capulus equilateralis* and *C. infundibulum* than in most other species, because when attached to the vaults of

[1] Variation exhibited by a Carbonic Gasteropod, Am. Geol., vol. III, June, 1889.

SYNOPTICAL TABLE OF CRINOIDS AND ASSOCIATED CAPULI.

Crinoids.	*C. chesterensis.*	*C. equilateralis.*	*C. infundibulum.*	*C. formosus.*	*C. quincyensis.*	*C. dumosus.*	*C. erectus.*	*C. parasiticus.*	*Sp. und.*
Gilbertsocrinus tuberosus.	..	*	..	..	..	..	..	..	..
Gilbertsocrinus typus.	--	*							
Actinocrinus verrucosus.	--	--	--	--	--	--	--	--	*
Physetocrinus ventricosus.	..	..	--	--	*				
Strotocrinus regalis.	--	*							
Dorycrinus immaturus.	--	--	--	*					
Agaricocrinus americanus.	--	*							
Eucladocrinus millebrachiatus.	--	--	*						
Arthroacantha punctobrachiata.	--	--	--	--	--	*	*		
Pterotocrinus acutus.	*								
Pterotocrinus depressus.	--	--	--	--	--	--	--	--	*
Pterotocrinus bifurcatus.	--	--	--	--	--	--	--	--	*
Poteriocrinus coccinus.	---	*							
Platycrinus hemisphericus.	--	*	*						
Platycrinus pileiformis.	--	--	--	--	--	--	--	--	*
Acrocrinus shumardi.	--	--	--	--	--	--	--	--	*
Cromyocrinus simplex.	--	--	--	--	--	--	--	*	
Marsupiocrinus cælatus.	--	--	--	--	--	--	--	--	*
Melocrinus globosus.	--	--	--	--	--	--	--	--	*
Pentremites godoni.	*								

crinoids the station of each individual is definitely known. As stated already, the first of these forms generally rests on flat-vaulted crinoids; while the second commonly adheres laterally to such echinoderms as *Platycrinus hemisphericus*. *Capulus equilateralis* when occupying the same position is pendant, the apex of the shell being directed downward instead of in the opposite direction as when resting on the ventral surface of such species as *Gilbertsocrinus*. The shell thus pendant exhibits a decided tendency to straighten, or uncoil, consequently becoming longer, the apex freeing itself completely from the body whorl. In comparison, therefore, with a representative example of *C. equilateralis* those shells resting on flat crinoidal vaults are very much depressed, the aperture proportionally broader and the spire more closely coiled. Those individuals attached laterally to crinoids have a tendency to become more conical, the aperture being relatively smaller, while the spire is entirely free from the last volution and the apex often extends to a considerable distance beyond the posterior margin of the aperture.

On the other hand *Capulus infundibulum* is commonly a more or less elongate conic shell. When attached to *Platycrinus* it often assumes a very different aspect. As growth proceeds the posterior side becomes relatively shorter, the apex slightly curved backwards and not unfrequently there is a marked tendency toward a strongly arcuate form.

II. Geographic and Geologic Distribution.

General Considerations. The Calyptræidæ are widely distributed both in space and time. The earliest appearance of this group of gasteropods is in the Calciferous strata of the Lower Silurian. From this time onward its development is rather rapid, and attains a considerable expansion in the upper paleozoic, where in numerical representation, size and variety of form it is rather remarkable. There is then a gradual and general decline toward the close of the paleozoic. The ancient Capuli are confined chiefly to Europe and North America, though two forms have been described from the Carbonic rocks of Australia. During Silurian and Devonian times New York seems to have been the great center of the development of this group; while in the interior of the American continent these gasteropods did not become common until the beginning of the Carbonic.

Range of American Species. Relative to the geographic and geologic distribution of the American species of *Capulus* during

Carbonic times the results thus far reached have been merely suggestive. In other zoological groups the evidence has been much more satisfactory of a reasonable co-ordination of the vertical and horizontal ranges of the various species, especially in the Carbonic strata of the Mississippi basin. In general the question of geographical distribution during geological time has appeared to elicit but little attention, partly, perhaps, by reason of the many difficulties encountered in such investigations; and partly on account of insufficient material for intelligent comparisons. It is now known that many species, though perhaps originally described under several different names, have a much wider geographical and geological distribution than has been supposed. Several of these species have already been indicated [1]; and it is certain that an extended study of the forms belonging to the various zoological groups, from diverse horizons and from localities widely separated geographically, would be productive of many important results in the elimination of a large number of now recognized species, thereby placing paleontological science on a much firmer basis for more accurate deductions and more suggestive conclusions relative to the true status of ancient biological phenomena. The long period of comparative quietness during the deposition of the Carbonic rocks of the Mississppi basin and the concomitant more or less undisturbed conditions of environment thus imposed were particularly favorable to a wide geographic dispersion of the various species, and to their persistency through long periods of time. The majority of the species of *Capulus* appear to be more or less widely distributed in space, especially such forms as *C. acutirostris, C. parvus, C. equilateralis* and others.

The Kinderhook forms of the genus are, on the whole, extremely unsatisfactory for systematic determination, since the most of them are merely internal casts. They form, however, an important feature of the fauna inclosed in these rocks. The Burlington and Keokuk species are very closely related, and in part extend through both epochs, after which the genus is of rare occurrence in the continental interior. It is of considerable interest to note that this numerical reduction after the close of the Keokuk was accompanied by a marked depauperization of the individuals which struggled through to the end of the Paleozoic. Through all the St. Louis, and Kaskaskia Coal Measures the species without exception are diminutive. The *C. acutirostris* of the St. Louis became reduced to

[1] Keyes: Proc. Acad. Nat. Sci. Phila., July 31, 1888.

nearly one-half the size it possessed in the Keokuk, notwithstanding the fact that this species had perhaps a wider geographical range than any other congeneric form occurring within the Mississippi basin and was therefore better adapted to preserve its full vigor, at least in some parts of its distribution.

The changes in the broad mediterranean sea that once spread over the interior of North America have been referred to elsewhere[1] in connection with the striking structural features of the crinoids of the Carbonic period and will also be considered in detail in another place.

Stratigraphical Catalogue.

CARBONIC.

Lower Carbonic.

Capulus piso (Walcott).
occidens (Walcott).

Kinderhook Beds.

Capulus formosus (Keyes).
lodiensis (Meek).
paralius (White & Whitfield).
subplicatus (Meek & Worthen).
cornuformis (Winchell).
haliotoides (Meek & Worthen).

Burlington Limestone.

Capulus biserialis (Hall).
cyrtolites (McChesney).
equilateralis (Hall).
fissurella (Hall).
infundibulum (Meek & Worthen).
latus (Keyes).
obliquus (Keyes).
quincyensis (McChesney).
tribulosus (White).

Keokuk Shales and Limestones.

Capulus acutirostris Hall.
equilateralis (Hall).
fissurella (Hall).

[1] Keyes: Genesis of the Actinocrinidae, Am. Nat., vol. XXIV, p. 243, *et seq.* 1890.

Capulus infundibulum (Meek & Worthen).
sulcatinus (Keyes).

St. Louis Limestone.

Capulus acutirostris Hall.

Kaskaskia Limestone.

Capulus chesterensis (Meek and Worthen).
ovalis (Stevens).

UPPER CARBONIC.

Lower Coal Measures.

Capulus spinigerus (Worthen).

Upper Coal Measures.

Capulus parvus Swallow.

III. DESCRIPTIONS OF SPECIES.

Generic Diagnosis. Shell depressed, subglobose, or obliquely subconic; body whorl very large. Aperture ample, expanded; labrum more or less sinuous, inner lip not anchylosed to the spire. Surface glabrate, plicate or sometimes spiniferous; lines of growth often imbricate.

The shells which have been referred to *Platyceras* present a manifold variety of forms. It is, therefore, not improbable that a fuller examination and comparison of all the known species will demand a somewhat different arrangement and subdivision of the group than that now existing. In this section the shell presents few salient characters for consideration. As already stated it is often with extreme difficulty that the forms of this group can be satisfactorily separated from certain varieties of *Platystoma* and various genera of Patelloid shells. In general, however, the test of *Capulus* is coiled, subspiral, arcuate or subconic with a relatively small spire and an immense, rapidly expanding body whorl, while the surface is usually without ornamentation. The large majority of the species of this group possesses tough, massive shells which are generally, therefore, in a much better state of preservation than most of the associated molluscan remains.

Muscular Scars. The internal scars so prominent in the shells of living *Capulus* and modern allied genera are seldom observable in paleozoic forms. Hence, having never noticed in individuals of the latter the peculiar horse-shoe shaped impressions, Hall[1] assigns this

[1] 12th Ann. Reg. Rep. 1859, p. 16.

as the only reason for regarding *Capulus* and *Platyceras* as distinct genera. Since the time that the American author first expressed this opinion, a sufficient number of fossil examples have been found to indicate clearly the real nature of these scars. A careful comparison shows that they are not very different from those of typical Capuli, though considerable variation is noticeable in the several forms and even in shells of the same species. Extended comparisons do not confirm the recent statement of M. Œhlert [1] who thus remarks: "Sur les moules internes des espéces que nous publions, nous avons egalement observé des impressions musculaires qui, tout en présentant certaines analogies avec celles des *Capulus* récents montrent néanmoins des caractères distincts, suffisants pour justifier la création du genre paléozoique que avait été prévu par Conrad, Phillips et Hall."

As exhibited in *C. infundibulum* and some other species the muscular scars consist of a transversely elliptic impression on each side connected by a narrow band traversing the posterior side of the shell. In adult examples the scars are situated about one-fourth the distance from the apertural margin to the apex. In some excellent internal casts of *Capulus protei* (Œhlert) from the lower Devonic of Mayenne the muscular impressions are somewhat different from those of congeneric species from America. The scar on the right side is comparatively large, oval and well defined; a narrow sinuous band passes around the spire posteriorly and terminates on the left side in an enlarged scar similar to, but much smaller than, that on the right. In some specimens the linear band does not appear to be perfectly continuous from one side to the other.

Capulus occidens (Walcott).

Platyceras occidens Walcott, 1884. Palæ. Eureka Dist., p. 254, pl. xxiv, figs. 9, 9a.

Capulus occidens Keyes, 1890. Am. Geol., vol. V.

Shell small, composed of about one and one-half volutions, the last rapidly expanding; spire minute; body whorl oblique, rather sharply rounded dorsally. Aperture large, irregularly triangular; labrum sharp, sinuous. Surface marked by numerous lines of growth; and apparently by a few small undefined longitudinal folds.

Horizon and locality. Lower Carbonic: Eureka District, Nevada.

This species appears to be more closely related to *C. cyrtolites* Mch., from the Burlington limestone, than to any other congeneric form of the Mississippi basin. The apex, however, is more closely

[1] Bul. Soc. géol. de France, (3), t. XI, p. 605.

coiled than in that species and the body whorl is much more expanded.

Capulus ? piso (Walcott).

Platyceras piso Walcott, 1884. Palæ. Eureka Dist., p. 254, pl. xxiv, figs. 7, 7a, 7b.

Shell below medium size, composed of about two loosely-coiled volutions, gradually expanding; body-whorl broadly rounded and, for the most part, free from the spire, which is rather small; several small obscure longitudinal folds are discernible toward the aperture. The latter is subcircular or subovate; lip sinuous. Surface exhibiting only numerous fine lines of growth.

Horizon and locality. Lower Carbonic: Eureka District, Nevada.

There is some doubt as to the correct generic reference of this species. The shell appears to differ in several important particulars from *Capulus* and it is not improbable that eventually this form will be placed elsewhere.

Capulus formosus (Keyes). [Plate II, fig. 8.]

Platyceras formosum Keyes, 1888. Proc. Am. Philosophical Soc., vol. xxv, p. 242, figs. 8 and 9. Reprint, p. 14.

Capulus formosus Keyes, 1890. Am. Geol., vol. V.

Shell arcuate, slightly oblique, enlarging rather rapidly to the ample, irregularly pentalobate aperture; posterior side rather short and concave; lateral slopes nearly straight. Apex obtuse. Surface marked by five broad well-defined longitudinal plications, each of which is composed of several smaller folds; these are crossed by sinuous lines of growth.

Horizon and locality Kinderhook beds: Marshall county, Iowa.

The two specimens of this species found are both attached to the vaults of specimens of *Dorycrinus immaturus* W. & Spr. described in the eighth volume of the Illinois Geological Survey. This species resembles, in some respects, *C. paralius* (W. & W.) but is simply arcuate instead of being coiled.

Capulus cornuformis (Winchell). [Plate II, fig. 5.]

Platyceras cornuforme A. Winchell, 1863. Proc. Acad. Nat. Sci., Phila., 1863, p. 18.

Platyceras cornuforme Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 294.

Shell small, arcuate, forming about half a volution, rapidly expanding; young specimens often broadly and obtusely subcarinate along the dorsum. Aperture irregularly oval or subcircular; margin sinuous. Surface glabrate; lines of growth scarcely discernible.

Horizon and localities. Kinderhook beds: Burlington, Iowa; and Lodi, Ohio.

This is one of the smallest of the Lower Carbonic species of the genus; but may have attained a larger size than the type specimen indicates. A large form from Lodi, Ohio, labeled *Platyceras cornuforme* by Meek seems to be more closely related to *C. paralius* (W. & W.) than with species in question.

Capulus haliotoides (Meek & Worthen).

Platyceras haliotoides Meek & Worthen, 1866. Proc. Acad. Nat. Sci., Phila., July, 1866, p. 264.

Platyceras haliotoides Meek & Worthen, 1868. Geol. Sur. Illinois, vol. III, p. 458, pl. xiv, figs. 3a, 3b.

Shell below medium size, very obliquely ovate, forming about two very rapidly expanding volutions, which are contiguous, except near the apertural margin; whorls rather compressed, somewhat sharply rounded along the periphery. Spire slightly elevated above the level of the body whorl. Aperture ample, oval; labrum sinuous. Surface marked by undulating lines of growth and often by a few low, obscurely defined ridges.

Horizon and localities. Kinderhook beds: Richfield and Newark, Ohio.

This form is commonly found only as internal casts and the surface markings are therefore rarely preserved. The species usually does not have the labrum touching the spire, nor the latter as closely coiled as is shown in the figures of Meek & Worthen.

Capulus lodiensis (Meek).

Platyceras (*Orthonychia*) *lodiense* Meek, 1871. Proc. Acad. Nat. Sci., Phila., 1871, p. 170.

Platyceras (*Orthonychia*) *lodiense* Meek, 1875. Geol. Sur. Ohio (Palæ.), vol. II, p. 313, pl. xiii, figs. 1a, 1b.

Shell below medium size, obliquely conic, anterior slope moderately convex, lateral slopes straight, or very slightly concave, posterior slope concave; a narrow rounded ridge extends anteriorly from near the apex to the labrum. Aperture subelliptic; margin somewhat sinuous. Surface apparently marked by fine lines of growth only.

Horizon and locality. Kinderhook beds: Lodi, Ohio.

Capulus lodiensis seems to be very closely related to *C. subplicatus*, with which it should, perhaps, be regarded as synonymous; the chief difference being simply the more plicate character of the latter. It has been elsewhere shown that the plications are extremely

variable and are dependent largely upon the accidental station of the mollusk. The type specimen is imbedded in a hard matrix—only the interior of the shell being exposed to view. Meek's figures were made from plaster casts of the interior, so that no surface markings are discernible.

Capulus paralius (White & Whitfield). [Plate II, figs. 1a, 1b.]

Platyceras paralium White & Whitfield, 1862. Proc. Boston Soc. Nat. History, vol. VIII, p. 302.

Platyceras paralium Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 294.

Capulus paralius Keyes, 1890. Am. Geol., vol. V.

Shell small, forming about two rapidly expanding volutions, which are not contiguous; apical portions minute, slender, laterally compressed, subangular along the dorsum, more or less distinctly plicate. Aperture irregularly pentagonal; labrum sharp, deeply sinuous, or somewhat serrate. Surface marked by few subimbricate lines of growth.

Horizon and localities. Kinderhook beds: Des Moines and Marshall counties, Iowa; Lodi, Ohio.

The apical portion of the shell is more slender and extended than the type would indicate from a casual examination. The smaller specimen figured (Plate II, fig. 1b) shows the spire perfectly preserved. The type (Plate II, fig. 1a) has the longitudinal folds much more prominent than is apparent in a representative specimen of the species. In some examples the plications are hardly noticeable. This species is widely distributed geographically, ranging from Le Grand, in central Iowa, to the southeastern part of the State and thence to Ohio.

Capulus subplicatus (Meek & Worthen).

Platyceras (*Orthonychia*) *subplicatum* Meek & Worthen, 1866. Proc. Acad. Nat. Sci. Phila. 1866, p. 265.

Platyceras (*Orthonychia*) *subplicatum* Meek & Worthen, 1868. Geol. Sur. Illinois, vol. III, p. 457, pl. XIV, figs. 4a, 4b, 4c.

Shell small, depressed, obliquely conical; anterior slope somewhat convex; posterior and lateral slopes slightly concave or straight; several large broad undefined plications extend from the apertural margin nearly two-thirds the distance to the apex. Aperture subcircular.

Horizon and locality. Kinderhook beds: Richfield, Ohio.

This species is known only from natural casts. The specimens exhibit well the muscular scars which are described as "obliquely elongated, subovate or sublunate, and vertically striated, placed a

little above the middle of each side and connected by a linear band passing around behind."

Capulus cyrtolites (McChesney). [Plate II, fig. 2.]

Platyceras cyrtolites McChesney, 1860. Desc. New Foss. Palæ. Rocks Western States, p. 71.

Platyceras cyrtolites Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 288.

Capulus cyrtolites Keyes, 1890. Am. Geol., vol. V.

Shell small, slender, arched; composed of about one volution; dorsally subangular, with a broad flattened area on each side; posteriorly somewhat plicate. Apical portion small, incurved, sometimes enrolled or contiguous. Aperture moderately large, subquadrangular; lip sharp, sinuous. Surface marked only by strong undulating lines of growth, which are often somewhat imbricated.

Horizon and localities. Burlington limestone: Burlington, Iowa; and Calhoun county, Illinois.

This species appears to be genetically related to *C acutirostris* (Hall) from the Keokuk and eventually the two forms may prove identical. *C. cyrtolites* is from the upper division of the Burlington limestone and differs very essentially from any known congeneric species from the same horizon.

Capulus biserialis (Hall).

Platyceras biserialis Hall, 1859. Geol. of Iowa, vol. I, pt. ii, Suppl., p. 90.

Platyceras biserialis Meek & Worthen, 1868. Geol. Sur. Illinois, vol. III, p. 509, pl. XV, figs. 3a, 3b.

Capulus biserialis Keyes, 1890. Am. Geol., vol. V.

Shell rather below medium size, somewhat ovate, subspiral, forming slightly more than one volution, regularly incurved. Aperture broadly oval; margin rather sharp, undulating, with a broad rounded sinus anteriorly. The expanded anterior portion of the shell marked on each side by a longitudinal row of long, conspicuous, hollow spines, about six in number. Surface smooth showing numerous fine, sinuous lines of growth.

Horizon and locality. Burlington limestone: Quincy, Illinois.

A marked characteristic of this form and also of *C. tribulosus* (White) is that the tubular spines are arranged in longitudinal rows, while in the few other American spine-bearing Capuli there is no regularity in the distribution of the spinous process. The spines are easily broken and hence are seldom preserved to their full length; often they are scarcely noticeable.

Capulus latus (Keyes.)

Platyceras latum Keyes, 1888. Proc. Am. Philosophical Soc., vol XXV, p. 242, figs. 10, 11. (Reprint., p. 14.)

Platyceras latum Keyes, 1889. Proc. Acad. Nat. Sci., Philadelphia, 1889, p. 290.

Capulus latus Keyes, 1890. Am. Geol., vol. V.

Shell large, depressed, forming about one and one-half volutions, very rapidly expanding from the apex to the aperture, but enlarging transversely much more than dorso-ventrally; posterior side comparatively very short. Apex small, incurved, but free from the body of the shell and nearly in the same plane as the general curvature. Aperture very large, campanulate, transversely elliptic; lip attenuate and slightly sinuous. Surface marked toward the aperture by a few small nearly obsolete folds, and by numerous sinuous lines of growth.

Horizon and locality. Burlington limestone: Burlington, Iowa.

This species is from the white compact layers of the upper division of the Burlington beds. The specimens like the majority of fossils from this stratum are usually more or less exfoliated.

Capulus obliquus (Keyes). [Plate II, fig. 3.]

Platyceras obliquum Keyes, 1888. Proc. Am. Philosophical Soc., vol. xxv, p. 241, figs. 12, 13. (Reprint., p. 13.)

Platyceras obliquum Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 290

Capulus obliquus Keyes, 1890. Am. Geol., vol. V.

Shell of medium size, irregularly oblong, subspiral, forming one volution; regularly enlarging, slightly more rapidly transversely than in the opposite direction, to the aperture. Apex large, obtuse, far removed from the body of the shell, which is broadly arcuate; very noticeably oblique to the plane of general curvature in the body of the shell. Aperture irregularly quadrangular in outline; margin sharp and more or less sinuous. Surface marked by several undefined longitudinal plications, which sometimes form longitudinal series of obscure nodes; these are crossed by numerous sinuous, often subimbricated lines of growth.

Horizon and locality. Burlington limestone: Burlington, Iowa.

This species is a transition between the so-called "Orthonychia" and "Platyceras" groups; and is one of the few of this type occurring in the American Carbonic.

Capulus quincyensis (McChesney). [Plate II, fig. 9.]

Platyceras quincyense McChesney, 1861. Desc. New Foss. Palæ. Rocks West. States, p. 90.

Platyceras quincyense McChesney, 1867. Trans. Chicago Acad. Sci., vol. I, p. 49, pl. vi, figs. 6a, 6b.

Platyceras (*Orthonychia*) *quincyense* Meek & Worthen, 1868. Geol. Sur. Illinois, vol. III, p. 510, pl. XV, figs. 5a, 5b.

Platyceras quincyense Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 290.

Capulus quincyensis Keyes, 1890. Am. Geol., vol. V.

Shell of medium size, broadly conical, often more or less elongated; expanding very rapidly and regularly from the central or subcentral apex to the aperture. Usually five broad, rounded ridges extend from near the apex to the aperture, which is consequently more or less prominently quinquelobate; the ridges are not unfrequently further divided into two or more smaller folds. Lip sharp, sinuous. Surface marked by subimbricating lines of growth and also by numerous small, often undefined, longitudinal costæ which do not appear in the cast.

Horizon and localities. Burlington limestone: Burlington, Iowa; and Quincy, Illinois.

The specimens described by McChesney and by Meek and Worthen were either exfoliated examples or internal casts; and this is the condition in which the species is usually found. Owing to the peculiar state of preservation the shells quickly crumble away in handling, leaving only the internal casts, but the distinctive quinquelobate character always renders them easily recognizable. In the examples figured by McChesney and also by Meek and Worthen the apices were wanting, but the individuals were not as imperfect as was supposed.

During the earlier periods of their growth many of the shells of *C. quincyensis* were very broad, but when attaining about one-third their maximum size the aperture abruptly became relatively smaller, leaving a sharp subangular ridge around the shell parallel to the apertural margin. This abrupt decrease in the expansion of the shell imparts to the natural internal casts the appearance of an apical truncation or fracture.

In its attachment to paleozoic crinoids the only forms with which *C. quincyensis* has thus far been found associated is *Physetocrinus ventricosus* (Hall), a species having a rather depressed hemispherical dome, in which the ventral opening has a subcentral location. The dome plates are small and numerous and frequently studded with small prominent tubercles or subspinous processes, which impart to the gasteropod shell series of minute corrugations extending over each of the larger folds.

Capulus tribulosus (White). [Plate II, figs. 4a, 4b.]

Platyceras tribulosum White, 1883. 12th Ann. Rep. U. S. Geol. Sur. Ter., pt. I, p. 186, pl. XLI, figs. 6a, 6b.

Platyceras tribulosum Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 290.

Capulus tribulosus Keyes, 1890. Am. Geol., vol. V.

Shell rather below medium size, subspiral, rather slender, forming about one volution; regularly expanding to the aperture. Apex incurved, far removed from the body of the shell. Aperture irregularly oval, usually more or less broadly lobed posteriorly; lip sharp, irregular, with usually a deep sinus anteriorly. Surface glabrate, but exhibiting numerous fine, closely arranged lines of growth; also marked by three longitudinal series of long tubular spines, extending from the apertural margin about three-fourths the distance to the apex. Of these spiniferous rows two are disposed laterally, one on each side and the third centrally and dorsally.

Horizon and locality. Burlington limestone: Burlington, Iowa.

This is one of the few spiniferous species belonging to the genus *Capulus*; and only two others of similar character occur in the American Carbonic rocks. It appears to be closely allied to *C. biserialis* (Hall) and may eventually prove identical with that form, from which it apparently differs only in having three, instead of two, rows of spines. Thus far it has been noted only in the upper division of the Burlington limestone, when it occurs in the thin sandy-clay partings, associated with delicate and beautifully preserved bryozoa. The type specimen is not a characteristic representative of the species, being in several particulars quite abnormal.

Capulus acutirostris Hall.

Capulus acutirostris Hall, 1856. Trans. Albany Institute, vol. IV, p. 31.

Capulus acutirostris Hall, 1858. Geol. of Iowa, vol. I, pt. ii, p. 665, pl. xxiii, figs, 14a, 14b.

Platyceras (*Capulus*) *acutirostris* McChesney, 1860. Desc. New Palæ. Foss. West. States, p. 71.

Platyceras uncum Meek & Worthen, 1866. Proc. Acad. Nat. Sci., Phila., 1866, p 264.

Platyceras uncum Meek & Worthen. 1873. Geol. Sur. Illinois, vol. V, p. 516, pl. XVII, fig. 1.

Platyceras acutirostris Whitfield, 1882. Bul. Am. Mus. Nat. Hist., vol. I, p. 67.

Platyceras acutirostris Hall, 1883. Indiana Geol. Rept. for 1882, p. 370, pl. XXXI, figs. 13-15.

Capulus acutirostris Keyes, 1890. Am. Geol., vol. V.

Shell below medium size, rather slender, strongly arcuate, forming from one to one and one-half volutions; posterior side for some

distance from the apertural margin nearly straight. Spire laterally more or less compressed; sometimes small and short, sometimes long, attenuate, simply incurved or enrolled. Aperture oval, or sub-circular; margin sharp, sinuous. Surface marked by somewhat imbricating lines of growth, and several obscurely defined longitudinal plications, the anterior one being usually larger than the others, and often forming a prominent subangular ridge.

Horizon and localities. Keokuk limestones and shales: Warsaw and Nauvoo, Illinois. St. Louis limestone: Spurgeon Hill and Bloomington, Indiana; Tuscumbia, Alabama.

This form appears to have a geographically wide distribution; and it also presents considerable variation, even within limited areas. It was originally described from Spurgeon Hill, Indiana, and like all the faunal remains of that locality is characteristically depauperate. *Platyceras uncum* M. & W. seems to be identical with this species, the imposed conditions of environment being more favorable to a normal development; and to the attainment of somewhat larger proportions.

Capulus equilateralis (Hall). [Plate II, fig. 11.]

Platyceras equilatera Hall, 1859. Geol. Iowa, vol. I, pt. ii, Supp., p. 89.

Platyceras equilatera Meek & Worthen, 1873. Geol. Sur. Illinois., vol. V, p. 518, pl. xvii, fig. 2.

Platyceras equilateralis Miller, 1877. Cat. Am. Palæ. Foss., p. 156.

Platyceras equilatera White, 1880. Indiana Geol. Rept. for 1880, p. 514, pl. vii, fig. 5.

Platyceras equilaterum Keyes, 1888. Proc. Am. Philosophical Soc., vol. xxv, p. 236, figs. 2 and 3.

Platyceras equilaterum Keyes, 1889. Am. Geologist, vol. III, p. 331.

Platyceras equilaterum Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 288.

Capulus equilateralis Keyes, 1890. Am. Geol., vol. V.

Shell medium, but often attaining a large size; extremely variable, hemispherical to oblique conical, with incurved spire, volutions one to two in number, free or contiguous, moderately enlarging for some distance from the apex and then rather abruptly and rapidly expanding. Aperture very large, broadly oval, or often nearly circular; lip thin, more or less undulating. Surface smooth, but toward the apertural margin exhibiting numerous, often strongly imbricating, sinuous lines of growth. Frequently many small obscure longitudinal folds are also present,

Horizon and localities. Keokuk limestone and shales: Keokuk and Bonaparte, Iowa; Warsaw and Niota, Illinois; Crawfordsville, Indiana. Burlington limestone: Burlington Iowa.

This species seems to be one of the most abundant gasteropods of the Keokuk beds; especially at Crawfordsville, Indiana, where the conditions of environment, during the deposition of the blue clayey shales of that locality, were uncommonly favorable to the development of this mollusk. Some of the shells from the locality mentioned have very considerable measurements: height 45 mm.; length along the dorsum, 95 mm.; breadth, 60 mm. Not only is the species under consideration variable in size but it is extremely so in form and in the configuration of the apertural margin. Perhaps no *Capulus* in all the Carbonic presents so wide a range of variation as does this species. Immature shells appear to be glabrate, but as growth proceeded they became more and more rugose and imbricate. The spire is as often contiguous as free and simply incurved; and in adult specimens it is relatively very small. The longitudinal folds are not unfrequently very pronounced and being few in number, impart a peculiar trilobate appearance to the shells; in other examples all traces of plications are wanting.

The extensive series of *C. equilateralis* from the Crawfordsville shales affords many interesting phases of the habits of these gasteropods, hitherto not elsewhere presented in such an eminently satisfactory manner. At this locality *C. equilateralis* is usually attached to the calyx of *Gilbertsocrinus tuberosus* (Lyon & Casseday) but the mollusk is not invariably associated with this particular species of crinoid, as Meek & Worthen[1] supposed. A number of typical examples of the Capulus in question have been observed adhering to *Platycrinus hemisphericus* Meek & Worthen [plate II, fig. 11] with which, however, is more commonly associated *C. infundibulum* (M. & W.). In *Gilbertsocrinus* the vault is relatively large, nearly flat, with the anal opening located midway between the center and margin. In both *G. tuberosus* (L. & C.) from the Keokuk shales and *G. typus* (Hall) from the Burlington limestone, the ventral plates are convex, or, as in many specimens very nodose. The growing margin of the gasteropod shell having adapted itself exactly to the irregularities of the surface of the crinoidal vault, necessarily was always more or less deeply sinuous, each sinus being produced by the nodosity of the vault plate in contact; while the small linguiform projection between two sinuses extended down between the nodes of two contiguous plates. The extreme nonparallelism of the lines of growth so conspicuously evident in the shells of many ancient

[1] Geol. Sur. Illinois, vol. V, p. 335.

Capuli is thus capable of being traced and especially in those examples in which the nodosity of the dome plates of the crinoid have reached a high development. This phenomenon of nonparallelism of the lines of growth is not therefore indicative of a change in station of the gasteropod as has been suggested at various times.

It has been clearly shown elsewhere[1] that shells of *C. equilateralis*, when adhering to flat surfaces are always very much depressed and have the aperture proportionately much more expanded than the average specimen, while the spire is closely incurved, even touching the body of the shell. When the gasteropod is found attached to strongly convex surfaces, or to the calyces of *Platycrinus* the shell enlarges less rapidly; and there is also a tendency in the apex to become free from the body-whorl and even to completely uncoil, often to such an extent as to approach closely some forms of the *C. infundibulum* type.

Capulus fissurella (Hall).

Platyceras fissurella Hall, 1859. Geol. Iowa, vol. I, pt. ii, Supp., p. 90.

Platyceras fissurella Meek & Worthen, 1873. Geol. Sur. Illinois, vol. V, p. 519, pl. XVII, fig. 4.

Platyceras fissurella Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 289.

Capulus fissurella Keyes, 1890. Am. Geologist, vol. V.

Shell massive, obliquely depressed conical, enlarging rapidly to the aperture; from apex to margin straight or somewhat arcuate anteriorly, slightly concave posteriorly. Apex obtuse, situated nearly over the posterior margin of the aperture, which is ample, oval or nearly circular; lip thick, rounded, very slightly sinuous. Surface marked by numerous gently undulating, somewhat irregular and often subimbricating lines of growth. Occasionally there are obscure indications of small longitudinal folds.

Horizon and localities. Keokuk limestone: Warsaw and Nauvoo, Illinois. Burlington limestone: Burlington, Iowa.

The specific name of this form is very inappropriate, having originated in a misconception on part of the author of the species as to the true nature of the apical perforation in the type specimen. It has been clearly shown by Meek & Worthen that the aperture in the apex is not a natural opening, but an accidental fracture in the shell.

Recently typical examples of *C. fissurella* have been found in the upper Burlington limestone, thus adding another case in support of the view lately[2] advanced that the faunas of the Keokuk and Bur-

[1] Proc. Am. Philosophical Soc., vol. XXV, p. 236.

[2] Keyes: American Journ. Sci., vol. XXXVIII, pp. 189–193.

lington limestones are much more intimately related biologically than had hitherto been generally regarded; and that many so-called Keokuk species are merely the subsequent genetic representatives of Burlington forms. The validity of their distinction simply on account of occurring in differently named geological horizons cannot be sustained. It is not to be supposed that the biologic sequence of two divisions as the Burlington and Keokuk, so closely related stratigraphically and lithologically, and deposited under identical quiet conditions should be so widely separated faunally as the described species from these limestones would indicate.

Capulus infundibulum (Meek & Worthen). [Plate II, fig. 10.]

Platyceras subrectum Hall, 1859. Geol. Iowa, vol. 1, pt. ii, Supp., p. 89 (not *P. subrectum* Hall, 1859, for a New York specimen).

Platyceras subrectum Hall, 1860. Twelfth Am. Reg. Rept. Univ. N. Y., p 18. (Not *P. subrectum* Hall, 1859.)

Platyceras infundibulum Meek & Worthen, 1866. Proc. Acad. Nat. Sci., Phila., 1866, p. 266.

Platyceras infundibulum Meek & Worthen, 1873. Geol. Sur. Illinois, vol. V, p. 517, pl. XVII, fig. 3.

Platyceras infundibulum Keyes, 1888. Proc. Am. Philosophical Soc., vol. XXV, p. 238, fig. 1.

Platyceras infundibulum Keyes, 1889. Proc. Acad. Nat. Sci., Phila., 1889, p. 289.

Capulus infundibulum Keyes, 1890. Am. Geologist, vol. V.

Shell more or less conical, often somewhat oblique, with usually many undefined longitudinal folds; apical portions slender, expanding regularly at first and then more rapidly. Apex attenuated, often slightly deflected toward the posterior side. Surface smooth, but toward the aperture marked by numerous undulating, frequently imbricating lines of growth.

Horizon and localities. Keokuk limestones and shales: Keokuk, Iowa; Warsaw, Illinois; Crawfordsville, Indiana. Burlington limestone: Burlington, Iowa.

The most closely allied form associated with this species is *C. fissurella* (Hall), from which it is distinguished in being proportionally more elongate, while the apical part of the shell is characteristically slender. Ordinarily the shell is more or less conspicuously plicate, but the folds are, for the most part, narrow, and usually irregular and broken.

For an elongated specimen Meek & Worthen[1] have indicated the name *Platyceras extinctor* "should it prove distinct," but the term

[1] Proc. Acad. Nat. Sci., Phila., p. 266, 1866.

cannot be regarded as having actually been proposed, while the form itself is manifestly only an attenuated internal cast of *C. infundibulum*. It however exhibits well the characteristic muscular impressions.

This species like *C. equilateralis* (Hall), with which it is usually associated, occurs in the Burlington limestone and ranges through the Keokuk. Its association with crinoids at Crawfordsville, Indiana, has been for the most part with *Platycrinus hemisphericus* M. & W.; while at Burlington it adheres to a structurally similar form, *Eucladocrinus millebrachiatus* W. &. Spr. The vault in the first species is very much elevated and the anal opening is situated laterally between, and slightly above, two arm bases. The dorsal cup is ornamented by numerous conspicuous rounded tubercles. As the growing shell increased in size the pliant apertural margin encountered successively the different nodes, which caused the lip at these points to deflect outward, giving rise to variously shaped prominences on the shell; when the tubercles were arranged in regular rows there appeared a series of narrow nodular plications. In many cases the gasteropod shell increased in size much faster than the echinoderm and the lip of the shell consequently often encompassed the two posterio-lateral arms and not unfrequently also the stem of the crinoid. The result was two large, deep sinuses in the anterior and one similar indentation in the posterior margin of the shell. The effect of the tubercles was to impart a similar sinuous character to the entire margin, hence the lip was always crenated during the latter part of the mollusk's existence. The continual change in the nature of the surface upon which the gasteropod shell rested also interfered with the uniform and regular growth along the apertural margin and the lines of growth are consequently often strongly imbricated.

Capulus sulcatinus sp. nov. [Plate II, figs. 12a, 12b.]

Shell of medium size, obliquely subovate, composed of two to two and one-half rather closely coiled or contiguous volutions, enlarging rapidly toward the aperture. Body whorl large and partly free from the small closely coiled spire; a broad rounded fold extends dorsally along the last whorl. Aperture broadly obovate; margin sharp, undulating, with a wide deeply rounded sinus anteriorly. Surface marked by numerous well defined, nearly parallel longitudinal ridges, with broad, rather shallow depressions between; lines of growth numerous, extremely sinuous.

Horizon and locality. Keokuk shales: Crawfordsville, Indiana.

This species occurs in the famous Crawfordsville crinoid beds, associated with *C. equilateralis* and *C. infundibulum* both of which are common species of that locality. It is one of the few regularly costate species of the genus and the only one of this character found in the Carbonic strata of America.

Capulus ovalis (Stevens).

Acroculia ovalis Stevens, 1858. Am. Jour. Sci, (2), vol. xxv, p. 261.

Platyceras laevigatum Meek & Worthen, 1866. Proc. Acad. Nat. Sci, Phila., 1866, p. 263. (Not *Acroculia lævigata* McCoy.)

Shell very small, subglobose; volutions about two an one-half in number, contiguous, rather rapidly expanding but not campanulate; spire very small. Aperture regularly subcircular or oval, but frequently somewhat flattened laterally; lip sharp, not sinuous. Surface glabrate; but under the magnifier exhibiting fine regular lines of growth.

Horizon and localities. Kaskaskia limestone: Union and Randolph counties, Illinois; St. Genevieve county, Missouri.

Capulus ovalis is one of the smallest of the lower Carbonic Capuli, having a height of only three to six millimeters and a maximum breadth of eight millimeters.

Capulus chesterensis (Meek & Worthen). [Plate II, figs. 13a, 13b, 13c, 13d.]

Platyceras (Orthonychia) chesterense Meek & Worthen, 1866. Proc. Acad. Nat. Sci., Phila., 1866, p. 265.

Platyceras chesterense Keyes, 1888. Proc. Am. Philosophical Soc., vol. XXV figs. 4 and 5.

Capulus chesterensis Keyes, 1890. Am. Geologist, vol. V.

Shell small, obliquely conical, with five nearly equidistant, longitudinal furrows, which alternate with broad flattened folds; expanding moderately to the aperture; usually more or less strongly arcuate, sometimes forming nearly half of a volution, thus bringing the apex above or even considerably beyond the posterior portion of the labrum. Apex more or less attenuated but often blunt. Aperture pentagonal, or irregularly subcircular; lip thick, rounded, with five deep, rounded sinuses. Surface marked by numerous subimbricated, broadly undulating lines of growth.

Horizon and localities. Chester division of the Lower Carbonic: Chester and Pope counties, Illinois; and Pulaski county, Kentucky.

This little species is found almost invariably attached to the vault of crinoids; and Meek & Worthen report one adhering to the side of *Pentremites godoni* DeFrance, "so as to entirely cover one of the

pseudo-ambulacral fields and two intermediate areas." The specimens from Kentucky are nearly all attached to *Pterotocrinus—P. acutus* Wetherby, *P. bifurcatus* Weth., and *P. depressus* Weth. In the first of these species the vault is very much elevated, being nearly three times the height of the dorsal cup. The first radial dome plates are produced into monstrous, alate processes, leaving only a small summit which is perforated for the anus. The margin of the growing gasteropod shell has followed closely the surface in contact; and in the majority of examples when the summit of the crinoidal vault was not sufficiently extensive for the support of the enlarging shell, the apertural margin has been prolonged into the interradial depressions, forming prominent, rounded, linguiform extensions; while the protruding, rounded upper edges of the alate dome-plates of the crinoid have given rise to five deep, broadly rounded sinuses in the lip of the molluscan shell. The lines of growth in the shell are therefore extremely sinuous, the undulations in the direction of the aperture being concave on the broad flattened folds, and convex in the furrows. In some specimens the furrows and folds have their origin very near the apex; a fact which is suggestive that the form of the shell and the configuration of the apertural margin may not have been entirely dependent upon the immediate surface of contact; but from a long continued habit of adhering to a crinoid presenting such remarkable ventral features as *Pterotocrinus*, the gasteropod gradually acquired after many generations, a decided tendency toward the quinquelobate form, which made itself manifest at an early period of the mollusk's existence, and perhaps even in the latter part of the embryonic stage.

In order to bring the mouth over the ventral aperture of the crinoid and at the same time rest securely on the limited, flattened summit at one side of which the anal opening was situated it was necessary for the gasteropod to have the anterior portion of the shell directed toward the posterior side of the crinoid—one of the few instances of the kind that has been noted, for almost invariably the front of the gasteropod shell is directed toward the anterior side of the echinoderm.

Capulus parvus Swallow. [Plate II, figs. 14a, 14b, 14c.]

Capulus parvus Swallow, 1858. Trans. St. Louis Acad. Sci., vol. I, p. 205.

Platyceras nebrascense Meek, 1872. U. S. Geol. Sur. Nebraska, p. 227, pl. iv, fig. 15.

Platyceras nebrascense White, 1875. Expl. W. 100 Merid., Vol. IV, p. 159, pl. xii, fig. 5.

Platyceras nebrascense White, 1884. Indiana Geol. Rept. for 1883, p. 159, p. xxxii, figs. 15 and 16.

Capulus parvus Keyes, 1890. Am. Geologist, vol. V.

Shell small, broadly arcuate, or obliquely recurved, forming nearly one volution; regularly and rather rapidly expanding to the aperture. Apex rather blunt; inclined or recurved to the right. Aperture ample, subovate; lip sharp, more or less regularly sinuous. Surface nearly glabrate but under a glass showing numerous undulating lines of growth, which are clearly visible nearly to the apex. The shell is also marked sometimes by several almost obsolete longitudinal folds.

Horizon and localities. Upper Coal Measures: Indiana, Iowa, Nebraska, Kansas and New Mexico.

The small specimen figured (plate II, figs. 14a and 14b) is considered the type of Swallow's species, now in the museum of the University of Missouri. A careful comparison shows the form described from Nebraska by Meek is only a more mature individual of *C. parvus*. Since, however, Swallow's species was poorly defined and was never figured; and as Meek was the first to give a clear dignosis of this form both by a full description and by good illustrations, it is questionable whether Meek's name should not really be retained for the form, *Platyceras nebrascense* having been almost universally applied to this species as occurring throughout the west.

Capulus spinigerus (Worthen).

Platyceras spinigerus Worthen, 1873. Geol. Sur. Illinois, vol. V, p. 594, pl. xviii, fig. 4.

Capulus spinigerus Keyes, 1890. Am. Geologist, vol. V.

Shell rather small, strongly arched; composed of less than one volution; very rapidly expanding to the aperture. Apex sharp, scarcely incurved. Aperture subovate; lip sinuous. Surface marked by many undulating, often somewhat imbricated lines of growth; and also by a few scattering spines; several low broadly rounded longitudinal ridges have their origin near the apex and extend to the aperture.

Horizon and locality. Lower Coal Measures: Brighton, Illinois.

This is one of the three spiniferous species of *Capulus* occurring in the Carbonic strata of America. The other two are from the Burlington limestone and have the spines arranged in longitudinal series while in *C. spinigerus* the spines are scattered over the surface of the shell. It is very probable that this form will prove to be identical with *C. trigonalis* of Stevens.

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IV. Spurious and Doubtful Species of Carbonic Capuli.

Platyceras bivolve White & Whitfield. (Proc. Boston Soc. Nat. Hist., vol. VIII, p. 302. 1862.) A careful examination of the type specimen appears to indicate that this form is a true *Platystoma* and it has accordingly been transferred[1] to that genus. Though somewhat resembling the young specimens of *Platyceras ventricosum* Conrad, as remarked by White and Whitfield, it differs very essentially from that form. The spire is much more elevated, being on a level or even above the surface of the body whorl; while the inner lip is much thickened, reflexed and anchylosed to the spire. *Platystoma bivolve* (W. & W.) has almost an exact counterpart among some forms of the upper Siluric species *Platystoma niagarense* Hall, from the Waldron (Indiana) shales.

Platyceras capax K. (Proc. Am. Phil. Soc. 1888, p. 241.) Probably synonymous with *C. equilateralis* (Hall).

Platyceras capulus Hall. (Geol. Sur. Iowa, vol. I, pt. ii, Supp., p. 91. 1859.) If recent identifications have been correct this species does not belong to the genus *Capulus*.

Platyceras extinctor Meek & Worthen. (Proc. Acad. Nat. Sci., Phila., p. 266, 1866.) Never formally proposed. It is evidently only an elongated variety of *Capulus infundibulum* (M. & W.).

Platyceras lævigatum Meek & Worthen. (Proc. Acad. Nat. Sci., Phila., 1866, p. 263.) Synonym of *Capulus ovalis* (Stevens). The name was preoccupied by McCoy.

Platyceras nebrascense Meek. (U. S. Geol. Sur. Nebraska, 1872, p. 227.) Only a more mature individual of *Capulus parvus* Swallow.

Platyceras pabulocrinus Owen. (Rept. Geol. Sur. Indiana, p. 364, 1862.) Proposed for a form similar to C. *infundibulum* (M. & W.), but without description.

Platyceras reversum Hall. (Geol. Iowa, vol. I, pt. ii, Supp., p. 91, 1859.) Manifestly is not a Capulus.

[1] Proc. Acad. Nat. Sci., Phila., 1889, p. 293.

Platyceras subrectum Hall. (Geol. Iowa, vol. I, pt. ii, Suppl., p. 89, 1859.) Preoccupied by Hall for an Upper Helderberg form. Synonym of *C. infundibulum* (Meek & Worthen).

Platyceras tortum Meek. (Proc. Acad. Nat. Sci., Phila., 1871, p. 171.) This species does not belong to *Capulus*. The general form, the flattened character of the upper half of the body whorl, the obtuse angularity toward the sutural line and the series of distinct parallel costæ running transversely over the volutions, as well exhibited in the type specimens, all indicate that the species is actually a partially uncoiled *Naticopsis*, probably not far removed from *N. ventricosa* N. & P. A similar tendency in the whorls to become separated is admirably shown in *Naticopsis gigantea* H. & W. from the Devonic; and also in *Platystoma niagarense* Hall from the upper Siluric. The shell of *Naticopsis torta* (Meek) is extremely thin and fragile, while the lines of growth are regularly and evenly curved, both of which characters are seldom exhibited in the ancient Capuli.

Capulus triplicatus Swallow. (Trans. St. Louis Academy Sci., vol. I, p. 205, 1858.) Too imperfect for description. Apparently does not even belong to the Gasteropoda. Probably a valve of a Myalina!

Platyceras uncum Meek & Worthen. (Proc. Acad. Nat. Sci., Phila., 1866, p. 264.) Synonym of *Capulus acutirostris* Hall.

Of the five following species nothing is known except the original descriptions which are very meager and are unaccompanied by figures. They are apparently identical with species already described; but inasmuch as authentic specimens have not been examined their synonymy will not here be considered. They are: *Platyceras hertzeri* Winchell, *Platyceras vomerium* Winchell, *P. quincuxense* McChesney, *P. hickmansense* McChesney and *Acroculia trigonalis* Stevens.

Explanation of Plate II.

Fig. 1. *Capulus paralius* (W. & W.) 1a. Lateral view of type specimen [Museum of University of Michigan]. 1b. A younger individual.

Fig. 2. *Capulus cyrtolites* (McC.) Lateral aspect.

Fig. 3. *Capulus obliquus* (Keyes). Lateral view of type.

Fig. 4. *Capulus tribulosus* (White). 4a. A rather small shell, from above. 4b. Same from side.

Fig. 5. *Capulus cornuformis* (Winchell). Lateral view of a small individual. [Coll. J. S. Newberry.]

Fig. 6. Calyx of *Platycrinus pileiformis* Hall showing the impression made by a calyptræan shell on the posterior side of the crinoid.

Fig. 7. Portion of the ventral surface of *Strotocrinus regalis* (Hall) showing the impression made by a growing shell of Capulus.

Fig. 8. *Capulus formosus* Keyes. Lateral view of type specimen, attached to *Dorycrinus immaturus* W. & Sp. [Coll. Wachsmuth and Springer.]

Fig. 9. *Capulus quincyensis* (McC.) View of an exfoliated specimen.

Fig. 10. *Capulus infundibulum* (M. & W.) A shell attached to the anal surface of *Platycrinus hemisphericus* M. &. W.

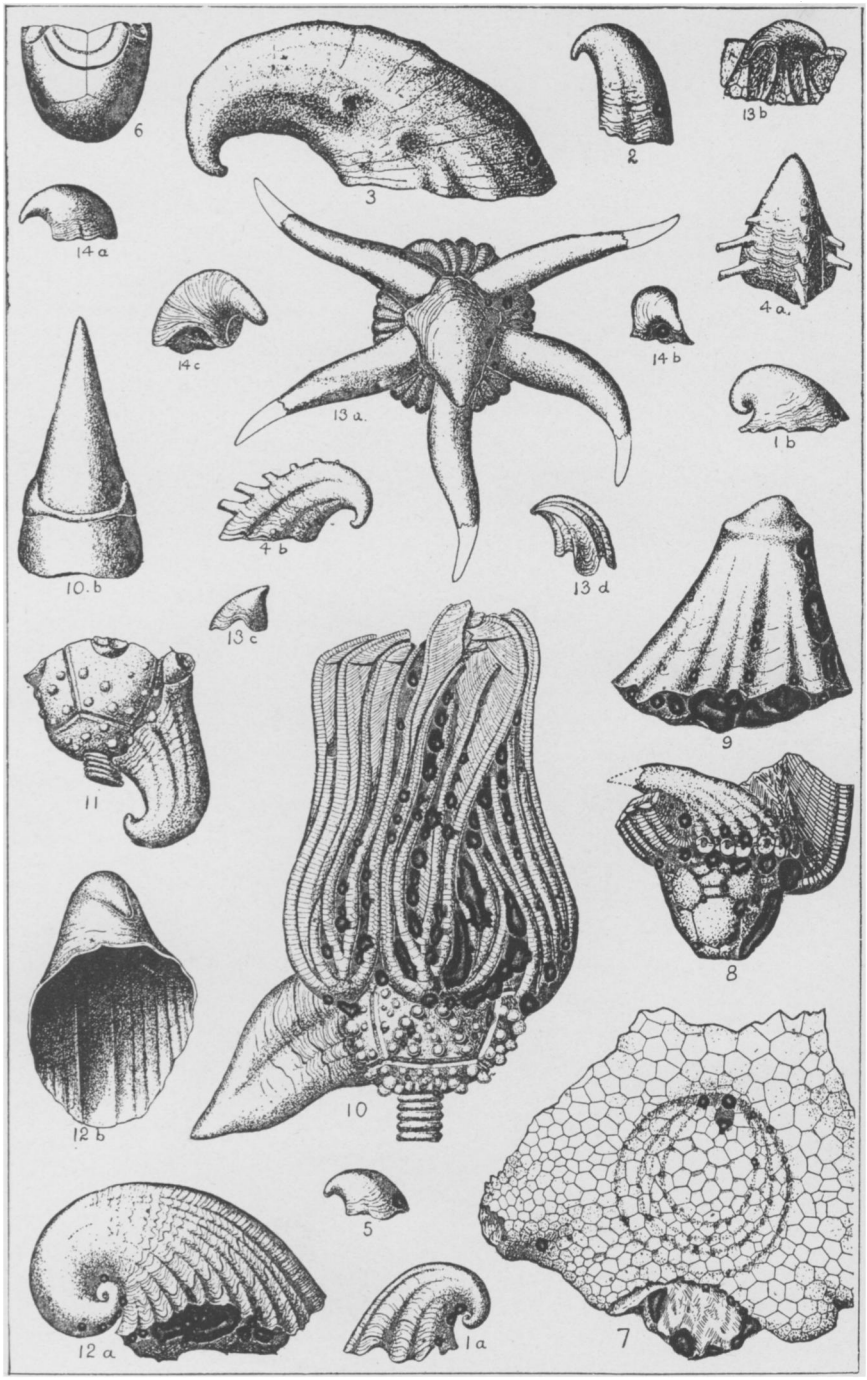
Fig. 11. *Capulus equilateralis* (Hall). An example adhering to the calyx of *Platycrinus hemisphericus* M. & W. [Coll. Wachsmuth and Springer.]

Fig. 12. *Capulus sulcatinus* Keyes. 12a. View of the type specimen. 12b. Ventral view of another individual.

Fig. 13. *Capulus chesterensis* (M. & W.) 13a. View from above of a specimen resting on the ventral surface of *Pterotocrinus acutus* Weth. 13b. Another example with the alate radial dome plates of the crinoid broken away. [Both from Collection of Wachsmuth and Springer.] 13c, 13d. Lateral aspects of two other individuals.

Fig. 14. *Capulus parvus* Swallow. 14a, 14b. Views of the type specimen [Museum State University of Missouri]. 14c. A larger example generally known as *C. nebrascensis* (Meek).

[Unless otherwise stated all specimens here figured are in the collection of C. R. Keyes.]



KEYES ON CARBONIC CALYPTRÆIDAE.